PREFACE

This report contains the findings of a water quality survey of Alton Bay, Lake Winnipesaukee, New Hampshire, conducted jointly by the Freshwater Biology Group (**FBG**) of the University of New Hampshire and the United Associations of Alton (**UAA**) in the summer of 1987.

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of 1987 results as well as more detailed "Introduction" and "Results and Discussion" sections. The description of methods and materials used by the lay monitors and the Freshwater Biology Group has been included in an appendix. While it is common practice to exclude this type of section from a "general" writing such as this, it is our goal to provide the association with a complete report which can stand on its own for comparison to past as well as future lake studies.

This is a Level III program report with tabular and graphic display of data and a more in-depth discussion of the water quality parameters. In addition, listings of data with statistical summaries appear in appendices along with a glossary of terms and a brief introduction to some important concepts of lake ecology. The more adventurous reader is referred to these last sections, as well as the materials cited in the references section, if there is interest in learning more about the dynamics of fresh water systems.

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ACKNOWLEDGEMENTS

This was the fifth year of participation in the Lakes Lay Monitoring Program (**LLMP**) for the United Associations of Alton. We would like to acknowledge Dr. Klaus Biemann for his dedication to the organization and maintenance of the **LLMP** for Alton Bay. As in the past, the program was well organized and the data collection was very successful. Lay Monitors were Clifton B. Chandler and William Hollenbeck (Site 22), Charles Griffen and Peter Whittemore (Site 24); Paul and Emily Todd (Site 25); Beverly and Richard DiVaio and J.Petro (Site 26); Rolf Dutzmann and Harold Smethurst (Site 27). The Freshwater Biology Group (**FBG**) congratulates the monitors on the quality of their work, and the time and effort put forth. We encourage these and other interested members of the United Associations of Alton to continue monitoring during the 1988 season. We would also like to acknowledge Mr. Clifton B. Chandler for taking the initiative to request financial assistance from the Governor's Office. The result of his actions was a substantial appropriation to the LLMP which will be used to update water sampling kits and expand the the current program.

Financial support of the monitoring program was provided by donations from a number of lake shore associations, their parent organization (**UAA**), and many individuals. Most important was the contribution by the Town of Alton, through the Conservation

Commission, which is a welcome demonstration of the support this monitoring program receives from the Town Officers.

The Freshwater Biology Group (**FBG**) is co-supervised by Dr. Alan Baker and Dr. James Haney and coordinated by Jeffrey Schloss. Members of the **FBG** summer field team included Jeff Schloss, Leanne Hussey, Doerthe Fuhlendorf, Paul Schofield and Camilla Girgus. Jeff was responsible for arranging the field trips, training lay monitors, supervising the research team, data interpretation and report writing. Leanne and Camilla were responsible for the preparation of chemical solutions, chlorophyll analysis, and data entry. Paul was responsible for phosphorus chemistry and analysis. All team members participated in field work and chemical analyses. In the fall, Elizabeth Ferrari assisted in sample processing, data organization and data entry, Dan Helsel processed phosphorus samples and Annette Grace counted zooplankton and assisted the coordinator. The **FBG** also acknowledges Ann Meade for her time volunteered.

The **FBG** would like to thank the Institute for Marine Science and Ocean Engineering of the University of New Hampshire for the partial funding of the coordinator position. Eileen Wong of the Department Zoology provided accounting and secretarial service. The College of Life Science and Agriculture provided lab and storage facilities. We would also like to recognize the UNH Office of Computer Services for the provision of computer time and data storage space.

Participating groups in the **LLMP** for 1987 included: The New Hampshire Audubon Society, Derry Conservation Commission, Nashua Regional Planning Commission, Center Harbor Bay Conservation Commission, Governor's Island Club Inc., Little Island Pond Rod and Gun Club, Walker's Pond Conservation Society, United Associations of Alton, the associations of Baboosic Lake, Beaver Lake, Berry Bay, Big Island Pond, Bow Lake Camp Owners, Lake Chocorua, Great East Lake, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Mendum's Pond, Merrymeeting Lake, Moultonbouro Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake, Nippo Lake, Pleasant Lake, Silver Lake (Madison), Squam Lakes, Sunset Lake, Lake Winona, and Wentworth Lake and the towns of Alton, Amherst, Hollis, Merrimack and Strafford.

NON-TECHNICAL SUMMARY

As in past years, the general water quality of Alton Bay was good.

1) Water transparency at the deep sites of Alton Bay measured by secchi disk was high, a sign of a clear, unproductive lake. The secchi disk was visible as far down as 10 meters (32.8 feet). This indicates the deepwater sites on the lake are usually low in dissolved color and suspended matter such as algae and particulates. Transparency averages for the six sites monitored in 1987 were greater than averages of the previous year.

2) Chlorophyll a concentrations for the surface waters of the deep sites of Alton Bay were generally low but slightly higher to levels measured in 1986. Chlorophyll levels indicate the extent of algae growth in the water. Concentrations in the mixed layer of water (the upper 3 to 10 meters) averaged 1.2 milligrams per cubic meter (mg m^{-3}, equivalent to 1.2 parts chlorophyll per billion parts water) at Alton Bay. Generally, concentrations below 3 mg m^{-3} are indicative of less productive, clear lakes.

3) Dissolved lakewater color levels in 1987 were low at site 24 and moderate to high at site 27. Small increases in water color from the natural breakdown of plant materials in and around a lake are not considered to be detrimental to water quality. However, increased color can lower water transparency, and hence, change the public perception of water quality.

4) Total phosphorus (nutrient) levels were low throughout Alton Bay. All open water sites had phosphorus concentrations below the 15 parts per billion (ppb) level, commonly thought of as the boundary between less productive and more productive lakes.

5) The total alkalinity, the lakes ability to buffer acid input, is low but comparable to other lakes in the program. The pH of the surface waters of the lake measured during FBG sampling trips was well within the optimum range for most aquatic organisms. Alkalinity stability indicates that Alton Bay has sufficient buffering capacity at this time to resist acidification.

6) The specific conductivity of the deep sites in the bay remained at low levels typical of clear, clean lakes. High conductivity values can indicate the presence of septic leachate or de-icing salt runoff.

7) In-depth analyses at three sites on Alton Bay disclosed the typical temperature stratification patterns for northern temperate lakes. Oxygen content of the bottom waters was high. Bottom water oxygen concentration remained above 5 milligrams per liter (the minimum concentration required for successful reproduction and growth of most coldwater fish) down to more than 18 meters depth. Carbon dioxide in the bottom waters was low to moderate. A high degree of mixing (down to 14 meters) occurred by the late August sampling dates.

8) The zooplankton and phytoplankton in the upper waters of the Alton Bay were in low amounts and generally indicative of a clear lake. During late August, chlorophyll samples taken at middle depths indicate the possibility of algal layering at the thermocline. Algal layering can be an indication of nutrient loading into the lake that has previously gone undetected. Continued monitoring should keep a careful watch on this phenomenon.

COMMENTS AND RECOMMENDATIONS

1) We recommend that each association, including the United Associations of Alton continue to develop their data base on lake water quality through continuation of the long term monitoring program. The data base will provide information on the short and long-term cyclic variability that occurs in the lake and eventually will enable more reliable predictions of water quality trends.

2) As we approach our tenth year in this cooperative lake monitoring effort we are expanding our program options with the help of a one time allocation from the state legislature (due to the efforts of Cliff Chandler, Dr. Biemann and contacts from other lakes). Some older equipment will be replaced and new equipment will include rain monitors and fish condition indexing kits. These materials will be provided at no cost to the association. The association should begin to look for interested members who would like participate in these studies. Cost for services have also decreased due to this support.

3) We recommend the continuation of alkalinity testing in 1988. Alkalinity indicates the ability of water to buffer acids, and may be more reliable than pH in predicting the effects of acidification on a lake. It is important to establish a data base for alkalinity in order to detect changes as early as possible,

especially in lakes such as Alton Bay where the buffering capacity is low.

4) FBG oxygen profiles from 1987 and other years have shown a metalimnetic (within the thermocline) oxygen peak in Alton Bay. Chlorophyll analyses in August by the FBG confirmed this occurrence. These layers may be an indication of nutrient loading. Occasional chlorophyll samples (late summer) from the thermocline, using the Meyer Bottle is suggested to monitor this phenomenon.

5) We suggest that all lay monitors initiate dissolved color testing on a weekly basis. In 1987 only two sites were monitored. There is no additional expense for this test. It requires the collection of filtrate from the chlorophyll processing, in small bottles that will be provided. The Freshwater Biology Group will analyze the filtrate by spectrophotometry. Dissolved color is very variable in Alton Bay and the data are important for interpretation of water transparency measurements.

INTRODUCTION

General Overview

The New Hampshire Lakes Lay Monitoring Program (LLMP) is a research and educational function of the Freshwater Biology Group (FBG) at the University of New Hampshire. The program involves the cooperative participation of lake residents, lake associations, conservation and planning commissions and local governments with University faculty and students. Developed in 1978 around Alton Bay, the program has grown to include more than 50 lakes throughout New Hampshire.

As a long-term research project, the LLMP is investigating the extent of lake degradation caused by perturbations such as acid rain, septic and agricultural runoff, and lakeshore development. Essentially, the volunteer monitors in the program collect data once each week. The data are stored on a computer, the results are analyzed periodically, and interpretive reports are written. The long-term data base permits the detection of both short and long-term changes of the water quality of the lakes. Results from the program are presented at national and international meetings and published in international journals.

As part of its commitment to education through the University, the LLMP trains several undergraduate and graduate students each year to collect and analyze lakewater samples for physical, chemical and biological parameters, and to interpret water quality data. In addition, more than 350 "lay" monitors have been educated about lake water quality and trained to monitor their own lakes.

As a service to the state and to local communities, the reports of the LLMP are available at cost, and should prove useful to lake residents, conservationists, developers and land-use planners. Also, LLMP staff members conduct workshops, lectures and informal talks on various lake related topics and hold advisory positions on many municipal and private conservation and planning boards. The LLMP is a not-for-profit organization with funding derived primarily from the participating groups and support services provided by the University.

Program Philosophy

Frequent sampling over many years is required to resolve long-term trends and make predictions on the water quality of our lakes. Consider the hypothetical lake in Figure 1. Sampling only once a year during June from 1975 to 1981 would produce a plot (Fig. 1A) suggesting a decrease in eutrophication (the "greening" of a lake). The actual long-term trend of the lake, increasing eutrophy, can only be clearly discerned by sampling more frequently for a longer period (Fig. 1B). Frequent monitoring carried out over the course of many summers can provide the information required to distinguish between short-term fluctuation ("noise") and long-term trends ("signal"). Intensive sampling of a number of lakes requires more labor than state agencies or universities are able to provide. Based on this premise, with much encouragement from lake associations within the state, the LLMP was conceived in 1978 and initiated in 1979.

The "grass roots approach" to volunteer water quality monitoring is readily apparent upon examination of a typical LLMP sampling kit. The quality of work that can be achieved with equipment constructed from wire, a wine or beer bottle, coffee cans, garden hose and yards of clothes-line has surprised even the most skeptical. These monitoring tools are fun to use and far less intimidating than expensive and complicated scientific apparatus. More importantly, all of the various LLMP sampling kits necessary for the monitoring of a lake can be made for less than the price of a commercially made water sampler.

A major factor in the continued success of our volunteer monitoring program is open communication between the lay monitors and the program staff. Monitors send samples and data sheets to the University on a weekly basis. Each lake has a contact person to coordinate monitoring and act as a liaison between monitors and the FBG. The FBG field team visits each full program lake at least once each summer to collect corroborative data and perform additional analyses. The site visits, along with yearly meetings/workshops held at the university, provide the monitors with program updates and allow for feedback on all aspects of the program.

The quality of work from the volunteers and the lack of constraints from outside sources enables the lay monitors to conduct a wide range of water quality tests (See Figure 2 for a breakdown of basic and optional testing by the lay monitors and the sampling conducted by the FBG field team). Expanded testing and surveys allow for a better understanding of the dynamic inter-relationships of the components of a lake system. Thus, the program provides the necessary information for the intelligent management of our lake resources at minimum cost.

Though not the first volunteer monitoring program, nor the largest in number of volunteers or lakes participating, the LLMP is the most extensive and diverse program of its kind. Through the commitment and enthusiasm of all participants the program is also one of the most long-lived, approaching ten years of operation.

RESULTS AND DISCUSSION OF LAY MONITOR DATA

Results from the lay monitors are presented separately from those obtained by the Freshwater Biology Group, as the two groups conducted separate research.

In 1987, weekly monitoring was done from five sites on Alton Bay (Fig. 3). Lay monitors collected data for water transparency, chlorophyll a concentration, dissolved color, total alkalinity and total phosphorus. See Appendix A for lay monitor data for 1983-1987.

Water Transparency

Secchi Disk depth is a measure of the water transparency. The deeper the depth of secchi disk disappearance, the more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and non-living particles) to absorb and scatter it. Secchi disk depths greater than 4 meters are typical of clear, less productive lakes. In 1987 values of water transparency at LLMP lakes were in the range 2.5 to 12 meters with a weighted average (by lake) of 6.4 meters.

Average secchi disk transparency (depth) was 8.5, 7.7, 8.0, 8.2, and 8.2 meters for sites 22 and 24 through 27 respectively. Transparency ranged from 5.6 meters (site 24) to 10 meters (sites 22, 25 and 27). The 1986 values were well within the range for clear, low productive, oligotrophic lakes. Secchi disk transparency fluctuated throughout the sampling season with lower transparency generally prevalent during July (Figs. 4-8).

For all sites pooled, the 1987 transparency average was greater (ie. the water was more clear) than 1984 and 1986 averages and less than the 1983 and 1985 averages (Fig. 9). The extent of the range of secchi disk depths encountered in 1987 was comparable to 1986 but less than all other previous years. Figures 10 through 15 display the average secchi disk value for the fives years of sampling by site to discern if any trends are apparent. Also included is the five year average of each site for comparison of individual years to the five year baseline. No significant increasing or decreasing trends in transparency is suggested by the data. For this current year, transparency was greater or equal to the five year average for all sites except 27.

Chlorophyll a

The chlorophyll a concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. **Eutrophic** lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Summer chlorophyll a concentrations average above 7 mg m^{-3} (one milligram per liter is equivalent to 1 part per billion) **Oligotrophic** lakes have low productivity and low nutrient levels and average summer chlorophyll a concentrations are generally less than 3 mg m^{-3}. **Mesotrophic** lakes are intermediate in productivity with concentrations of chlorophyll a generally between 3 mg m^{-3} and 7 mg m^{-3}. In 1987 chlorophyll a concentrations in LLMP lakes were in the range 0.1 to 7.1 mg m^{-3} with a weighted average (by lake) of 1.5 mg m^{-3}.

Chlorophyll a concentrations were in the range from 0.2 (sites 22 and 26) to 2.6 (site 24) milligrams per cubic meter (mg m^{-3}) at Alton Bay. Average chlorophyll concentrations were all low, 1.1, 1.5, 1.3, 0.5 and 1.2 mg m^{-3} for sites 22 and 24 to 27 respectively. Thus based on 1987 average chlorophyll concentrations, Alton Bay would be classified as oligotrophic. Generally, chlorophyll concentrations were greatest in late June to early July, decreased in late summer and then increased as fall approached (Fig. 16).

The pooled Alton Bay chlorophyll data indicate the 1987 average was less than 1984 and 1986 averages, greater than the 1985 average and comparable to the 1984 average (Fig. 18). The variation in chlorophyll values throughout 1987 (as extent of range) was less than all previous years except 1985. The five years of chlorophyll data collected suggest that chlorophyll has been slightly increasing for the past three years at sites 22, 24 and 27 (Figs. 19, 21 and 24) while no trends are yet apparent at sites 25 and 26 (Figs. 22 and 23) which have had alternating years of high and low chlorophyll values. All sites had 1987 chlorophyll averages slightly greater than the five year site average except for site 26. It should be noted however that site 26 was not sampled in June when chlorophyll levels were high.

Continued monitoring is necessary to determine if increasing chlorophyll levels are a long-term trend.

Dissolved Color

The dissolved color of lakes is generally due to dissolved organic matter from humic substances, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters.

Color is commonly expressed in units of a platinum color standard (ptu). To put the color concentrations in perspective, New Hampshire Lakes studied in 1987 by the Freshwater Biology Group had a range of dissolved color of from essentially 0 ptu to 137 ptu with an unweighted average of 17 ptu. Color samples collected at Alton Bay were in the range of 6 to 19 ptu at site 24 and 13 to 37 ptu at site 27 (see figure 17). Thus, the dissolved color was low for the bay site but moderate to high for the northernmost site sampled.

Total Phosphorus

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources primarily originate from anthropogenic activity in a watershed.

Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton.

Total phosphorus concentrations at the lake sites ranged from 2 to 14 (site 22) parts per billion (ppb) and averaged 4 ppb , well below the 15 ppb level commonly considered as the boundary between less productive and more productive lakes.

Alkalinity

Alkalinity is a measure of the buffering capacity of the lake water. The higher the value the more acid that can be neutralized. Typically lakes in New Hampshire have low alkalinities due to the absence of carbonates and other natural buffering minerals in the bedrock of lake watersheds.

Lay monitor measured alkalinity for all sites in Alton Bay had a range of 4.9 to 6.7 mg $CaCO_3$ liter^{-1}. Average alkalinity was 5.7, 6.3, and 6.2 mg $CaCO_3$ liter^{-1} for sites 22, 24 and 27 respectively. For the years it has been monitored, the alkalinity at Alton Bay has been low but stable.

RESULTS AND DISCUSSION OF FBG DATA

The Freshwater Biology Group (FBG) visited Alton Bay on 30 July and 26 August 1987. The lake was sampled for several chemical, physical and biological parameters at two of three sites (22, 24 and 26) on each trip.

Water Transparency

The secchi disk depth measured on 30 July by the FBG was 9.2 meters at site 22 and 8.8 meters at site 24. On 26 August values were 8.7 and 8.5 meters for sites 24 and 26 respectively. Transparency values are comparable to lay monitor data and indicate good corroboration between the two groups.

Chlorophyll a

Chlorophyll a concentrations from the integrated samples were in the range from 0.6 to 2.1 mg m^{-3} on Alton Bay. As with the secchi disk data, the monitor and FBG results compare well.

Dissolved Color

Dissolved color was in the range 4 to 9 platinum color units (ptu) at Alton Bay. Indicating low dissolved color at the deep sites 22. 24 and 26.

Total Phosphorus

Samples for total phosphorus were taken at the deep lake site from an integrated sample of the mixed upper waters and at the lake bottom. Phosphorus concentrations in the upper waters were in the range from 1 to 8 micrograms per liter (parts per billion; ppb). Levels were highest during June at site 22.

Alkalinity

Total alkalinity of the surface waters was in the range 4.9 to 5.3 mg $CaCO_3$ $liter^{-1}$. FBG results on the two dates were well within the range of lay monitor results throughout the summer. These are low values as the average alkalinity of New Hampshire lakes is approximately 9 mg $CaCO_3$ $liter^{-1}$ but the 1987 average alkalinity of all LLMP lakes was 6 mg $CaCO_3$ $liter^{-1}$.

pH

The pH is a way of expressing the acidic level of lake water, and is measured with an electrical probe sensitive to hydrogen ion activity. The pH scale has a range of 1 (very acidic) to 14 (very "basic" or alkaline) and is logarithmic (ie: changes in 1 pH unit reflect an order of magnitude, ie: 10 times, difference in hydrogen ion concentration). Most aquatic organisms tolerate a limited range of pH and most fish species require a pH of 5.5 or higher for successful growth and reproduction.

Surface pH was 5.9 to 6.0 in July increasing to 6.8 to 6.9 on the August date sampled. Low alkalinity generally results in fluctuating pH levels. The range of surface water pH for all **LLMP** lakes was 4.8 to 7.5. The pH decreased with depth at all deep sites. This can be attributed to greater carbon dioxide concentration in the bottom waters. At present the pH of the

Alton Bay is fluctuating but well within the optimum range of many aquatic organisms.

Decreasing alkalinity over a period of a few years can have serious effects on the lake ecosystem. In a study on an experimental acidified lake in Canada (Schindler et al 1985) gradual lowering of the pH from 6.8 to 5.0 in an 8-year period resulted in the disappearance of some aquatic species, an increase in nuisance species of algae and a decline in the condition and reproduction rate of fish. During the first year of Schindler's study the pH remained unchanged while the alkalinity declined to 20 percent of the pre-treatment value. The decline in alkalinity was sufficient to trigger the disappearance of zooplankton species, which in turn caused a decline in the "condition" of fish species that fed on the zooplankton. Thus it is important to continue monitoring these parameters as well as to start monitoring fish condition to provide baseline data to detect for any deleterious effects of acid rain.

Specific Conductivity

The specific conductance of a water sample indicates concentrations of dissolved salts. Leaking septic systems and de-icing salt runoff from highways can cause high conductivity values. Conductivity values at Alton Bay were in the range of 48 to 58 micro-Siemans. This suggests that the bay is receiving little salt runoff or septic input near these deep sites.

Stratification in the Deep Water Sites

Profiles of temperature for the deep sites studied show a distinct pattern of temperature stratification where a layer of warmer water (the **epilimnion**) overlies a deeper layer of cold water (**hypolimnion**). The layer that separates the two regions is characterized by a sharp drop in temperature with depth and is called the **thermocline** or **metalimnion**.

The epilimnetic depth for the Alton Bay was 9.25 and 8.0 meters in June for sites 22 and 24 respectively and progressed to 12 and 14 meters in August for sites 24 and 26 respectively (Figs. 25 and 26). The hypolimnion, which began at approximately 15 meters on both dates, had a range of temperature between 10 and 13 degrees C.

Dissolved Oxygen and Free CO2

Oxygen concentration was high in the epilimnion and remained at high to moderate concentrations in the bottom waters. Oxygen in the lower waters is important for maintaining a fit, reproducing, cold water fishery. Trout and salmon generally require oxygen concentrations above 5 mg per liter in the cool deep waters. Oxygen above the lake bottom is important in limiting the release of nutrients from the sediments and minimizing the collection of undecomposed organic matter. Alton Bay maintained oxygen levels greater than 5 mg per liter down to below 18 meters.

Carbon dioxide in the hypolimnion was moderate in Alton Bay. Carbon dioxide is generated and can accumulate in aquatic systems as a result of the respiration of a wide variety of organisms in the water. Plants (including the phytoplankton) take up free carbon dioxide and produce oxygen during the day, but respire at night along with the aquatic animals and bacteria. Carbon dioxide usually accumulates in the bottom waters of more productive systems where large amounts of organic material, produced within and around the lake, support large bacterial populations. Breakdown of organic matter, respiration and fermentation, by the bacteria in the water and sediments, consumes oxygen and releases carbon dioxide. Increases in dissolved carbon dioxide result in the decrease of the lakewater pH.

Metalimnetic Algal Populations

An increase in oxygen at the metalimnion (thermocline) was found at both sites during the July sampling. This suggested the presence of a layer of algae within this region that is not apparent from surface monitoring. As this oxygen maximum phenomena had occurred in some previous years testing should be initiated to check for **metalimnetic algal populations**, algae that layer out at the thermocline and generally go undetected if only epilimnetic (point or integrated) sampling is undertaken. Chlorophyll concentrations from samples taken at the metalimnion were greater than integrated sample values at sites 22, 24 and especially at site 26.

Phytoplankton

The planktonic community includes microbial organisms that represent diverse life forms, including photosynthetic as well as non-photosynthetic types, and including bacteria, algae, crustaceans and insect larvae. Phytoplankton samples were taken at all FBG monitored sites. Zooplankton are considered below in a separate section.

Because planktonic algae or "phytoplankton" tend to undergo rapid seasonal cycles on a time scale of days and weeks, the levels of populations found should be considered to be most representative of the two collection dates and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

The composition and concentration of phytoplankton in Alton Bay was typical of open-water plankton in clear lakes of low alkalinity. Numbers were low. The dominant species at all sites on both dates were the Chrysophyceae, a class of "golden" or "golden-brown" photosynthetic organisms. Among the most abundant of the golden algae this year was the colonial golden alga Dinobryon (Figs. 26 and 27). The sub-dominant algae at site 24 on both dates were members of the Bacillariophyceae or "diatoms", which usually tend to be most abundant in April-May and October-November (Fig. 27). At site 22 on 30 July the sub-dominant algae were cryptomonads (Fig. 28 B), particularly Chroomonas. This algal class are essentially ubiquitous, and populations of these poorly-understood flagellates are often concentrated in hard-water lakes as well as acidic waters such as bogs. Site 26 had bluegreen bacteria as the subdominant phytoplankton on 26 August. Cyanobacteria (blue-green bacteria) tend to be more abundant in nutrient enriched lakes, but their concentration at site 26 was relatively low.

Concentrations of less than five hundred organisms per milliliter are a second indication, along with the specific composition of the plankton, that the trophic status of Alton Bay is unproductive or oligotrophic. Careful microscopy of the type utilized in this study can discern as few as 10 to 50 cells ml^{-1}, fewer than are found in some of the most unproductive waters, or as many as 100,000 to 1,000,000 cells ml^{-1}, as found in highly productive, nutrient-enriched eutrophic lakes.

In general, when whole lakewater is taken into consideration, ultra-clean lakes with minimal nutrient loading tend to support fewer than about 500 organisms per milliliter, mesotrophic systems support perhaps 2000 to 4000, and eutrophic lakes can support in excess of 10,000 (even millions) of organisms per milliliter. Thus, the combination of quantity per milliliter and quality or distribution of species is a useful and sensitive indicator of the trophic state of a lake.

Zooplankton

There are three groups of zooplankton that are generally dominant in lakes: the **protozoa**, **rotifers** and **crustaceans**. Most research has been devoted to the last two groups although protozoa may be found in substantial amounts. Of the rotifers and the crustaceans, time and budgetary constraints made it necessary to sample only the larger zooplankton (macrozooplankton; larger than 150 microns). Thus, zooplankton analysis was restricted only to the larger crustaceans. The crustaceans can be divided into two groups, the **cladocerans** (which include the "water fleas") and the **copepods**.

Macrozooplankton are an important component in the lake system. The filter feeding of the herbivorous ("grazing") species may control the population size of selected species of phytoplankton. The larger zooplankton can be an important food source for juvenile and adult planktivorous fish. All zooplankton play a part in the recycling of nutrients within the lake.

Zooplankton undergo seasonal population cycles and the results discussed below are most representative of the two collection dates and not necessarily of other times during the ice-free season, especially during the early spring and late fall.

The macrozooplankton concentration on Alton Bay on 30 July was high, 22.5 and 12.4 organisms per liter for sites 5 and 6 respectively. On 13 August values reached 18.3 at site 1 and 13.7

at site 6. Concentrations between 1 and 10 per liter are considered moderate, concentrations over 10 per liter are considered high. Copepods dominated the macrozooplankton community at all sites and dates sampled (Figs. 29 and 30). Immature copepods (nauplii) were in high numbers in July along with the predatory cyclopoid copepods. Calanoid copepods were the dominant herbivores ("phytoplankton eaters") in August. The bay contains two different species of the "water-flea" genus Daphnia (indicated with a D before the species name in Figures 29 and 30). The high diversity of species found at Alton Bay is generally a sign of a "healthy" lake.

REFERENCES

American Public Health Association.(APHA) 1985. Standard Methods for the Examination of Water and Wastewater 16th edition. APHA, AWWA, WPCF. Washington, D.C.

Baker, A.L. 1973. Microstratification of phytoplankton in selected Minnesota lakes. Ph. D. thesis, University of Minnesota.

Carlson, R.E. 1977. A trophic state index for lakes. Limnol. Oceanogr. 22:361-379.

Edmondson, W.T. 1937. Food conditions in some New Hampshire lakes. In: Biological survey of the Androscoggin, Saco a nd coastal watersheds. (Report of E.E. Hoover.) New Hampshire Fish and Game Commission, Concord, New Hampshire.

Forsberg, C. and S.O. Ryding. 1980. Eutrophication parameters and trophic state indices in 30 Swedish waste-water receiving lakes. Arch. Hydrobiol. 89:189-207

Gallup, D.N. 1969. Zooplankton distributions and zooplank-ton-phytoplankton relationships in a mesotrophic lake. Ph.D. Thesis, University of New Hampshire.

Haney, J.F. and D.J. Hall. 1973. Sugar-coated _Daphnia_: a preservation technique for Cladocera. Limnol. Oceanogr. 1 8:331-333.

Hoover, E.E. 1936. Preliminary biological survey of some New Hampshire lakes. Survey report no. 1. New Hampshire Fish and Game Department, Concord, New Hampshire.

Hoover, E.E. 1937. Biological survey of the Androscoggin, Saco, and coastal watersheds. Survey report no. 2. New Hampshire Fish and Game Department, Concord, New Hampshire.

Hoover, E.E. 1938. Biological Survey of the Merrimack watershed. Survey report no. 3. New Hampshire Fish and Game Department, Concord, New Hampshire.

Hutchinson, G.E. 1967. A treatise on limnology, vol. 2. John Wiley and Sons, New York.

Lind, O.T. 1979. Handbook of common methods in limnology. C.V. Mosby, St. Louis.

Lorenzen, M.W. 1980. Use of chlorophyll-Secchi disk relationships. Limnol. Oceanogr. 25:371-372.

New Hampshire Water Supply and Pollution Control Commission. 1981. Classification and priority listing of New Hampshire lakes. Staff report no. 121. Concord, New Hampshire.

Newell, A.E. 1970. Biological survey of the lakes and ponds in Cheshire, Hillsborough and Rockingham Counties. Survey report no. 8c. New Hampshire Fish and Game Department, Concord, New Hampshire.

Newell, A.E. 1972. Biological survey of the lakes and ponds in Coos, Grafton and Carroll Counties. Survey report no. 8a. New Hampshire Fish and Game Department, Concord, New Hampshire.

Newell, A.E. 1977. Biological survey of the lakes and ponds in Sullivan, Merrimack, Belknap and Strafford Counties. Survey report no. 8b. New Hampshire Fish and Game Department, Concord, New Hampshire.

Schindler, D.W., et al. 1985. Long-term ecosystem stress: Effects of years of experimental acidification on a small lake. Science. 228:1395-1400.

Sprules, W.G. 1980. Zoogeographic patterns in size structure of zooplankton communities with possible applications to lake ecosystem modeling and management. in W.C. Kerfoot ed. Evolution and Ecology of Zooplankton Communities. University Press of New England. Dartmouth. pp642-656.

U.S. Environmental Protection Agency. 1979. A manual of methods for chemical analysis of water and wastes. Office of Technology Transfer, Cincinnati. PA-600/4-79-020.

Vollenweider, R.A. 1969. A manual on methods for measuring primary productivity in aquatic environments. International Biological Programme. Blackwell Scientific Publications, Oxford.

Wetzel, R.G. 1983. Limnology. Saunders College Publishing, Philadelphia.

METHODS OF LAY MONITORS

Lay monitors receive their initial training either on-site or on campus from a member of the **FBG**. Workshops covering new techniques are usually offered on a yearly basis and updates may be held on-site during an **FBG** sampling trip.

This year data were collected on five parameters: thermal stratification, water clarity (secchi disk depth), chlorophyll a concentration, dissolved color and total phosphorus. Whenever possible, testing was done weekly between the hours of 9 am and 3 pm, the period of maximum sunlight penetration into the water. All samples and data were mailed or hand delivered to the **FBG** at UNH for analysis.

Thermal (temperature) profiles were obtained by collecting lakewater samples at several successive depths using a modified Meyer bottle (Lind, 1979). A weighted, stoppered, empty bottle was lowered to a specific depth. At that depth, the stopper was pulled, allowing the bottle to be filled with water. The bottle was quickly pulled back up to the surface where the temperature of the sample was taken with a Taylor pocket thermometer, and recorded in degrees C. This procedure was repeated at one meter intervals through the epilimnion (upper water column), at one-half meter intervals throughout the metalimnion (depths at which the temperature change is greater than 1 degree C per meter) and at one meter intervals through the hypolimnion (depths below the metalimnion).

Water clarity was measured by lowering a secchi disk (approximately 20 cm. or 8 inches) through the water off the shaded side of the boat, and noting the average of the depths at which it disappeared upon lowering and reappeared when being raised (the cord attached to the secchi disk is marked in one tenth of a meter for the first half meter and in one-half meters thereafter). Water clarity was determined while holding a view-scope just below the surface to eliminate effects of surface reflection and wave action. This was repeated two or three times, and an average to the nearest one-tenth of a meter was recorded.

Chlorophyll a concentration was used as an index of algal biomass that is useful in determining the trophic state of the lake. A weighted plastic tube (10 meters in length) was lowered through the epilimnion to the top of the metalimnion (the depths of the epilimnion and metalimnion are determined from the temperature profile). The end of the tube above water is folded to shut off the water flow into or out of the tube. The weighted end of the tube is pulled up out of the water with an attached cord, trapping an integrated sample of water representing the "upper lake" in the tube. This sample is poured into a blue plastic 2.5 liter bottle and stored in the shade until chlorophyll filtration could be done.

Water samples for chlorophyll _a_ filtration were filtered through a 0.45 micron membrane filter under low vacuum. Damp filters, containing chlorophyll-bearing algae, were air-dried for at least 15 minutes, in the dark, to prevent decomposition or bleaching of the chlorophyll on the filter. A sample of the filtrate was poured into a 60 ml plastic bottle for the determination of dissolved water color. These filters and bottles were delivered to UNH where members of the **FBG** analyzed them for chlorophyll _a_ and dissolved water color (see Methods of the Freshwater Biology Group).

METHODS OF THE FRESHWATER BIOLOGY GROUP

The Freshwater Biology Group (**FBG**) research team took two trips to the Alton Bay and conducted several tests which included measurements of sunlight penetration into the water, dissolved oxygen, temperature, alkalinity, free (unbound) carbon dioxide, pH, specific conductivity, chlorophyll a, dissolved color, total phosphorus, and a survey of the microscopic plants (phytoplankton) and animals (zooplankton). The **FBG** also processed chlorophyll a, dissolved color, and phosphorus samples provided by the lay monitors. The input, storage and analysis of all **LLMP** data is also the responsibility of the **FBG**.

Field and Laboratory Methods

On the lake, a dissolved oxygen and temperature profile was taken using a Yellow Springs Instruments Model 54A Oxygen/Temperature meter with a submersible probe. Readings were taken at one-meter intervals throughout the epilimnion and hypolimnion, and at one-half meter intervals through the metalimnion.

Sunlight and skylight penetration into the water was measured with a Whitney submersible photometer model LMA-8A, off the sunny side of the boat. The coefficient of light extinction was calculated from the relative light intensities measured.

Samples of lake water chemistry to be analyzed for dissolved oxygen, alkalinity, free (unbound) carbon dioxide, pH, and specific conductivity were collected with a 3-liter Van Dorn bottle at depths which represented the surface, mid-epilimnion, metalimnion, and hypolimnion. Alkalinity, free carbon dioxide, and pH samples were stored on ice in 250 milliliter polyethylene bottles and were analyzed in the field within 1 to 2 hours of sampling. Specific conductivity samples were analyzed in the FBG lab at room temperature.

In addition to the oxygen profile taken, the dissolved oxygen (DO) concentration of specific lakewater samples (epilimnetic and hypolimnetic) were determined chemically with the azide modification of the Winkler method (EPA 1979). The precision of the method provides a standard for the electronic probe. Water is collected in 350 ml biological oxygen demand (BOD) bottles and fixed with two reagents, manganese sulfate and alkali-iodine-azide. A loose precipitate (floc) of manganic hydroxide forms that is equivalent to all dissolved oxygen originally present in the sample. Concentrated sulphuric acid is added to the bottle which causes a stoichiometric release of dissolved iodine equal to the original amount of dissolved oxygen present. A known quantity of sample is then titrated to an equivalence point using .0250N phenylarsine oxide titrant (similar to, but more stable than, sodium thiosulphate which may also be used) and a starch indicator solution. The end-point is reached when the purple colored iodine-starch complex is reduced and the solution becomes colorless. The amount of titrant added is recorded to the nearest 0.1 ml and concentrations are reported to the nearest 0.2 milligrams dissolved oxygen per liter.

To determine the alkalinity, lake water samples were titrated with 0.002 N sulphuric acid in the presence of the indicator methyl red/bromocresol green to a pH of 5.1 (grey endpoint) and 4.6 (pink endpoint). The amount of titrant used (dilute sulphuric acid) was recorded to the nearest 0.1 ml, equivalent to milligrams of calcium carbonate per liter. Values reported can be converted to microequivalents of calcium carbonate using a multiplication factor of 20.

"Free" carbon dioxide concentration was determined by titrating the fresh lakewater samples with 0.0027 N sodium hydroxide to a final endpoint pH of 8.3, in the presence of the indicator dye phenolphthalein.

Lakewater pH was measured with a digital pH meter (Beckman model phi 44) equipped with a combination probe (Orion Co.) and an automatic temperature compensating probe. The meter was calibrated with pH 4 and pH 7 buffer solutions and then the probe was allowed to equilibrate in the lake water for at least thirty minutes prior to sample analysis.

Specific conductivity was measured with a Barnstead Conductivity Bridge Model PM-70CB , with a model B-10 probe (cell constant = 1.0). Corrections were made for sample temperatures with a standard curve of potassium chloride solution conductivity versus temperature. Results are reported as micro-Siemens (uS; where uS equals umho cm^{-2}) standardized to 18^{o} C.

Samples to be analyzed for chlorophyll a, total phosphorus, and phytoplankton were collected with a vertical tube sampler into a 2.5 liter dark plastic bottle. Chlorophyll samples were filtered through a 0.45 micron membrane filter and air-dried in the dark until analysis. The chlorophyll a content was analyzed by extracting the chlorophyll with a 95% acetone solution saturated with magnesium carbonate. The samples were then centrifuged and their light absorbance read at two standard wavelengths (663 and 750 nanometers) with a Baush and Lomb model 710 spectrophotometer equipped with 50mm cuvettes. An absorptivity value of 84 gm $liter^{-1}$ cm^{-1} (Vollenweider 1969) was used for calculating the concentrations.

Dissolved color samples of the filtrate from **FBG** and lay monitor chlorophyll filtrations was determined by reading the absorbance of the samples at two different wavelengths (440 and 493 nanometers) in a 50mm light path. The two readings were converted to the more widely used platinum cobalt color values (ptu) using standard curves of the absorbance of chloroplatinate.

Phosphorus samples were preserved with 1.0 milliliter of concentrated sulphuric acid and refrigerated until analysis. Also, phosphorus samples from lay monitors were received by the **FBG** in a refrigerated or frozen state, and stored cold until analysis. To determine the total phosphorus content, ammonium persulfate and 11 N sulfuric acid was added to digest the total phosphorus, and the samples were autoclaved for thirty minutes at 250 to 260 degrees C. Reagents included potassium antimony tartrate, ammonium molybdate, and a solution of ascorbic acid mixed fresh before each sample run (E.P.A. 1979). Absorbance of the blue phosphorus complex was measured with a spectrophotometer at 650 nanometers. A standard curve of the absorbance of a potassium phosphate (monobasic) solution to convert the readings to total phosphorus concentrations. Each sample was analyzed twice and an average of the two values taken as the phosphorus content in parts per billion (ppb).

Phytoplankton samples were preserved with iodine (Lugol's solution) immediately after collection. Algae were later identified and counted with an inverted microscope after settling for 24 hours in 5 or 10 ml counting chambers. At least 200 individual algal "units" were counted with a modified scan technique (Baker, 1973). Phytoplankton are reported to species level whenever possible.

Zooplankton samples were collected with a plankton net (30 centimeter diameter, 150 micron porosity) towed vertically through the oxygenated portion of the water (>0.5 ppm oxygen). Samples were immediately preserved in a 4% formalin-sucrose solution (Haney and Hall, 1973). Organisms were identified to species whenever possible. Subsampling, whenever necessary, was done with a 1 ml Hensen-Stemple pipette. Repeated subsamples were analyzed until at least 100 organisms were counted.

Data analysis

Incoming data are received through the mail during the sampling season and are first filed in an "incoming data" book. This provides temporary storage until the corresponding chlorophyll and/or phosphorus sample for each data sheet is analyzed. All data, including date, lake, site, secchi disk depth, chlorophyll a and phosphorus concentrations, alkalinity, and color measurements, are filed and stored on the FBG computerized data-management system that utilizes a mainframe DEC VAX-8650 computer and an IBM compatible microcomputer (Zenith Data Systems 158). With full use of relational data bases, such as S1032 and Dbase III+ data can be easily retrieved by lake, date, station or by parameter and used for individual reports and program summaries for each year.

Statistical treatment of the data from each lake, produced for level III reports, includes a comparison of seasonal tendencies found throughout the year, monthly means for the different parameters tested, and confidence levels for each site. The same comparisons are made on a yearly basis if the lake has been in the program for two years or more. Where sufficient data are available from several years, regression analyses and other statistical tests can be performed. Such analyses may identify trends and help explain variations in the data (eg. secchi disk depth, chlorophyll a, color). In addition, data from a lake may be compared with other lakes in the program, other computerized data bases (New Hampshire Water Supply and Pollution Control, New Hampshire Fish and Game, EPA Surface Water Survey and others) and to published water quality classifications.

Trophic boundaries of Forsberg and Ryding (1980) of transparency, chlorophyll a, and total phosphorus are used as criteria in discussions of the trophic state of the program lakes. Phytoplankton are reported both as species and classes. Crustacean zooplankton were classified into one of four categories depending on their size (large or small) and their feeding preferences (herbivore or predator) with a modified version of criteria from Sprules (1980). The differences in abundance between the different groups allow for a more complete description of the zooplankton community and the trophic classification of lakes.